Microscale Chemical Heterogeneities in Brazilian Oxisols

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Introduction: Oxisols, the old, highly weathered soils common on stable land surfaces in tropical regions, are widespread in Brazil. The clay fractions of Oxisols consist predominately of the end products of chemical weathering, kaolinite, gibbsite, goethite, and hematite. Oxisols are major agricultural soils in Brazil because they tend to have favorable physical properties because much of the clay occurs in stable, sand-sized (1,000 to 50 μm) soil aggregates. Much information is available on the bulk chemical composition of Oxisols, but little on how elements are distributed over micrometer scales within aggregates. Given the stability of Oxisol aggregates and the long period of weathering, one might expect gradients to occur as elements are depleted from the aggregate surfaces by plant uptake and leaching. Our objective was to assess the microscale chemical heterogeneity in Oxisol aggregates.

Methods and Materials: We selected five major soil classes in the Triângulo Mineiro region in the western part of the state of Minas Gerais, Brazil and collected undisturbed soil samples at depths of 10 and 90 cm from sites that should not have received anthropogenic additions of trace elements. Thin sections were carefully prepared and mounted to assure that no trace element impurities were accidentally introduced. We used the synchrotron x-ray microprobe at beamline X26A at the National Synchrotron Light Source, Brookhaven National Laboratory to obtain data on trace elements at natural, uncontaminated levels down to a detection limit of ~2 mg kg^{-1}, with a spatial resolution of ~10 µm. Major element concentrations were obtained with a conventional electron probe microanalyzer.

Results: There was no evidence of chemical gradients from the core to the edge of the aggregates, except for a slight Si depletion at the edge. The distribution of chemical elements in the soils follows a "hot-spot" pattern where trace elements are highest in: (i) sand-sized primary Al-silicate minerals; (ii) sand-sized primary grains of Ti and Fe oxides; (iii) pieces of old organic matter, including charcoal; (iv) fresh roots and (v) Mn and Fe nodules. The hot spots themselves are randomly distributed within the soil (Marques, 2000). Elemental distributions within the soil plasma (the clayey matrix) are very homogeneous at the scale we studied. Although Oxisols are generally poor in primary minerals, we found a number of primary minerals in several thin sections. Primary minerals are high in elements such as K, Mg and Na. Sand-sized grains of Ti and Fe, magnetites and ilmenites, are high in trace elements like Cr, Cu, and Zn. Magnetites and ilmenites in soils derived from basalt show much higher trace element contents than magnetites and ilmenites from soils derived from other rock types. There are, however, large variations in trace element contents of magnetites and ilmenites within the same soil. Organic material exhibits an interesting behavior. Pieces of roots that were apparently alive when the samples were collected are high in Ca. Pieces of old organic material, like charcoal, are depleted in Ca but are enriched in Cu and, in some cases rare earth elements (REE) like Ce, Nd, Sm, and Yb. We hypothesize that charcoal in the soil is a sink for Cu because Cu has a strong affinity for organic ligands. The rare earth elements may have been concentrated by the plants, but detection of REEs may also be the result of less interference from Fe in the organic matrix as compared to the Fe-rich inorganic soil material. Like magnetites and ilmenites, pedogenic Mn and Fe concretions are also high in trace elements, especially when they happen to be very rich in Mn.

Conclusions: Except for Si, we found no evidence for elemental gradients within the clayey matrix of these highly weathered soils. Elemental contents followed a pattern of “hot spots” randomly distributed throughout the soil.

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References:

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